Landscape and Urban Planning 173 (2018) 23–32

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research Paper

Ecosystem services management: An evaluation of green adaptations for urban development in Dhaka, Bangladesh

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ARTICLE INFO

Keywords:
Urban ecosystem services
Green adaptation
Climate change
Social acceptance
Economic feasibility
City

ABSTRACT

We evaluated green adaptation strategies (parks, gardens, green roof, rainwater harvest, green façades/wall, porous pavement, and green and blue belts) in the context of urban development and potential climate change impacts for the city of Dhaka, Bangladesh. Our review of relevant literature revealed substantial environmental (cooler and cleaner environment), economic (reduced energy demand, avoided cost of drainage maintenance, increased land values) and social (higher social interaction, improved mental and physical health) benefits arising from the maintenance and development of ecosystem services in major cities. Our evaluation of green adaptation strategies was undertaken with household surveys in three wards of Dhaka, expert interviews, and our personal experiences. Rooftop gardens/agriculture had very high social acceptance (85%) and economic feasibility and was commonly practiced in Dhaka, particularly among house owners. Pocket park, green roof, rainwater harvest, green façades/wall, porous pavement, and community garden were all considered to be highly feasible for implementation with collective efforts but had lower social acceptance. Many respondents were unwilling to pay for green adaptation strategies even knowing their benefits. Our research revealed that successful implementation of beneficial green adaptation will require public participation at all stages supported through awareness raising campaigns. Enforcement of laws and strong commitment from the government was also considered to be beneficial. However, more transparent cost-benefit analyses promoting the conservation of ecosystem services is required, particularly for resource-poor Dhaka. Green adaptations make cities more resilient to pressures from demographic change and climate change increasingly relevant in the developing world.

1. Introduction

More than half of the world's population (54%) live in urban settings and this is expected to increase to 66% by 2050 (United Nations., 2014). Urbanization is problematic in developing countries (Khadka & Shrestha, 2011; Rana, 2011) as *ad hoc* development and high population growth exerts pressure on social, economic, and environmental wellbeing (Zinia & Kroeze, 2015). This is particularly the case for Dhaka, Bangladesh, one of the world's most densely populated cities. The residents of Dhaka also face climate change (particularly extreme heat, and extreme weather events) and poverty. Green adaptation strategies for maintenance or improvement of ecosystem services can present an effective response but, to date, no formal or coordinated activities have progressed.

In considering ecosystem services and associated green adaptation strategies, urban areas are often categorized as separate ecosystems (see Bolund & Hunhammar, 1999; Grimm & Redman, 2004; Mcintyre, Knowl-Yánez, & Hope, 2000; Niemelä et al., 2010). To evaluate green adaptation strategies for Dhaka, we define ecosystem services as those ecosystem functions that contribute to human wellbeing (MA, 2005; TEEB, 2010). Common services provided by urban ecosystems include production of fruits, grains and seeds; carbon sequestration; microclimate regulation; noise abatement; air, water and pollutant filtration; pollination; and recreation (e.g., boating, fishing, picnic) (Bolund & Hunhammar, 1999; Escobedo, Kroeger, & Wagner, 2011; Haase, 2015; Zinia & McShane, 2018).

Green infrastructures, ecosystem-based adaptation or eco-infrastructures are well-known urban ecosystem services management strategies (Betancourth, 2011; Cameron et al., 2012; Geneletti & Zardo, 2016). Integration of urban green spaces with other urban infrastructure can be effective adaptive responses to, for example, extreme heat events (Hansen & Pauleit, 2014). Importantly, for developing countries, green adaptation responses present affordable options, utilize ecosystems for multifunctional purposes, and involve multiple stakeholders (Goodess et al., 2013; Hulsman & Van Wesenbeeck., 2011).

Feasibility is one key concern essential to evaluate green adaptation

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https://doi.org/10.1016/j.landurbplan.2018.01.008
Received 9 May 2017; Received in revised form 9 January 2018; Accepted 18 January 2018
Available online 04 February 2018
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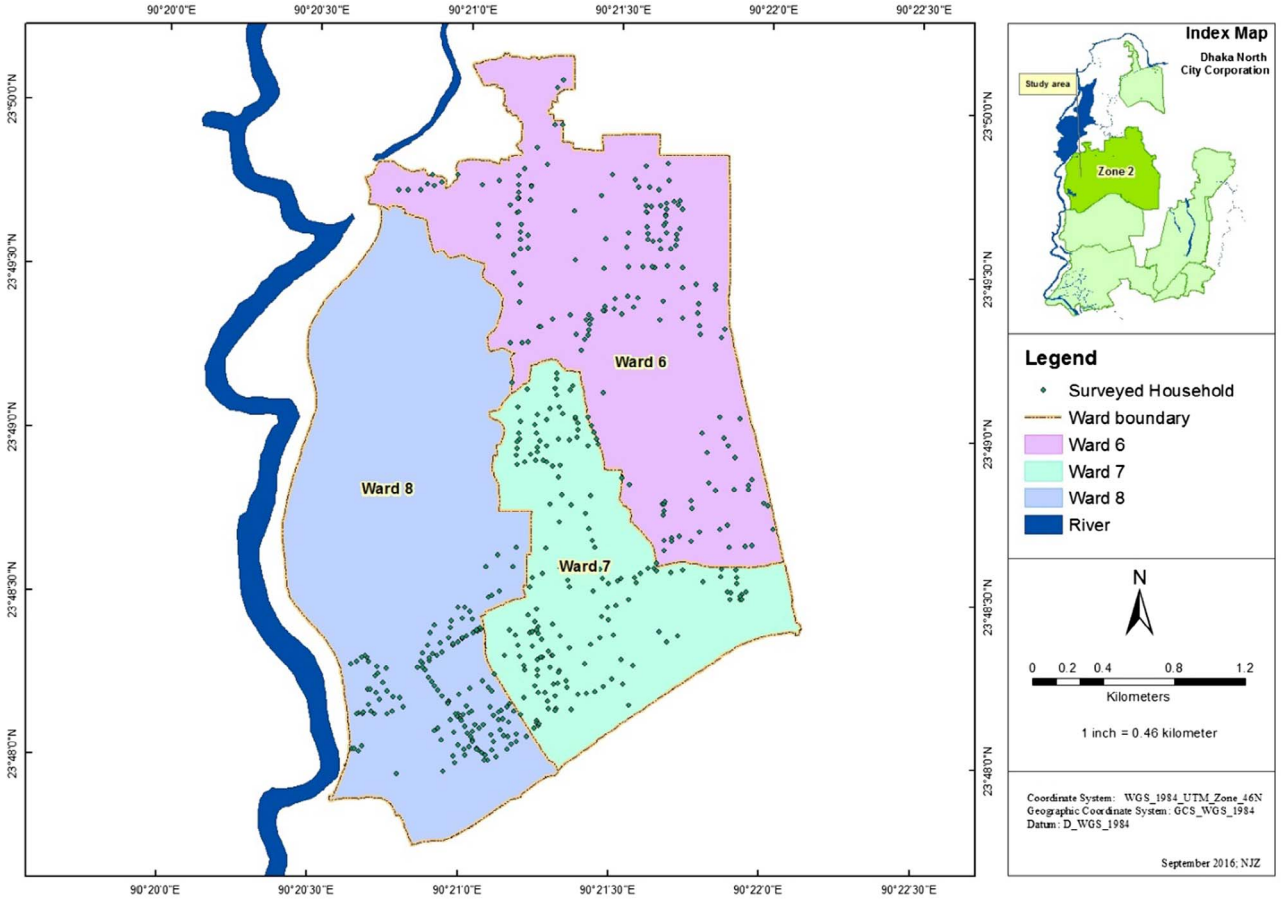

Fig. 1. Location of the study area.

strategies for ecosystem services management. There is a clear distinction between economic and financial feasibility analyses. Economic analysis evaluates a proposed intervention in terms of economic (cost, benefit), social and environmental issues concerning its worthiness for the community and the developer or user. Financial analysis considers the cash flow (income and expenses) associated with the proposed intervention (Halil, Nasir, Hassan, & Shukur, 2016; Liang & van Dijk, 2010). Several studies consider both analyses: Liang and van Dijk (2010) for decentralized waste water reuse systems, Giurco, Bossilkov, Patterson, and Kazaglis (2011) for water treatment and industrial water reuse synergies and Halil et al. (2016) for green building projects. We assess economic feasibility in a qualitative manner focusing on individual and collective affordability, that is, the purchasing power (Jana, Bardhan, Sarkar, & Kumar, 2016) for implementing green adaptation strategies in Dhaka.

Social acceptance is crucial for successful implementation of strategies and projects for current and future planning (Khorsand, Kormos, MacDonald, & Crawford, 2015; Yuan, Zuo, & Huisingh, 2015). We define social acceptance as an individual or a group of local resident's support(s) (high to low) reflected in their preferences for implementability of green adaptation strategies. This follows the findings of related studies (e.g. Chin, Choong, Wan Alwi, & Mohammed, 2014; Wüstenhagen, Wolsink, & Bürer, 2007; Zhao, He, Johnson, & Mou, 2015) including studies particularly focused on green adaptation strategies (see Jung, Moula, Fang, Hamdy, & Lahdelma, 2016; Zhao et al., 2015).

Dhaka is the capital city of Bangladesh located at the confluence of three major rivers, the Ganges, the Brahmaputra and the Meghna. More than 12 million residents occupy a total area of about 1464 km^2 (BBS, 2013). Its annual population growth rate is 3.5% (BBS, 2012). Urban expansion is expected to occur in the peri-urban (fringe) areas (Roy, 2009). Typical of Bangladesh more generally, Dhaka is experiencing extensive land use change led by rapid urbanization (Dewan & Yamaguchi, 2009). Mostly, agricultural lands are converted to built-up areas, brick fields are established in the fringe areas, forests are destroyed to meet fuel needs, and illegal encroachment of common resources such as rivers, lakes and wetlands by developers is prevalent and is affecting ecosystem services (Rana, 2011). Growth of informal settlements such as slums is contributing to environmental pollution in Dhaka (Dewan & Corner, 2014). Urbanization, along with urban expansion, poses severe impacts on ecosystems (wetlands, rivers, parks, agriculture land, forest) at multidimensional scales which is a matter of concern (Byomkesh, Nakagoshi, & Dewan, 2012; Zinia & Kroeze, 2015). There is an urgent need to assess the states of these ecosystems and to implement measures to stop further deterioration and to maintain or improve ecosystem services for human wellbeing. Yet, no empirical research has been undertaken thus far on green adaptation strategies for managing ecosystem services in Dhaka.

Thus, we have been motivated to evaluate relevant literature to formulate a list of green adaptation strategies for urban ecosystem services management. From this assessment, we contextualize green adaptation strategies given the extant literature on urban development and related impacts on ecosystem services more generally. We then evaluate social acceptance and economic feasibility of green adaptation strategies for urban development of Dhaka. We focus on green adaptations that are possible to implement individually and/or collectively, are less technology and capital-intensive, and require minimum government support. Our empirical study is novel in that as it integrates social, economic, and environmental aspects of urban development: the first research for Dhaka city.

Table 1
Green adaptations at city scale contributing to ecosystem services through urban green management.

Green adaptations for managing green spaces	Contribution to ecosystem services	Urban area (city, country)	References
Rooftop garden (intensive green roof)	- Microclimate regulation - Influence on air quality - Aesthetics - Recreation	Kuala Lumpur, Malaysia	Rahman et al. (2015)
Green/living roof	- Storm water management - Urban flood prevention - Microclimate regulation - Influence on air quality - Encourage urban biodiversity - Food availability - Pollination - Aesthetics	Toronto, Canada; Philadelphia, USA; Stuttgart, Germany; Berlin, Germany; Augustenborg, Malmö, Sweden; Basel, Switzerland	Kazmierczak & Carter (2010), Francis and Lorimer (2011)
Private/domestic/home garden	- Biodiversity conservation - Habitat creation - Cognitive development (ecological knowledge) - Social activities - Microclimate regulation - Aesthetics - Food availability - Pollination - Influence on air quality - Erosion prevention - Urban flood prevention	Phoenix, Arizona; Maastricht, The Netherlands; North West Province & Gauteng Province, South Africa, Stockholm, Sweden; Dunedin, New Zealand; Edinburgh and Leicester, UK; León, Nicaragua	Beumer and Martens (2015), Goddardet al. (2010), Davoren et al. (2015)
Green courtyards	- Urban flood prevention - Microclimate regulation	Berlin, Germany	Kazmierczak and Carter (2010)
Green facades	- Aesthetics - Urban flood prevention - Microclimate regulation	Berlin, Germany	Kazmierczak and Carter (2010), Francis and Lorimer (2011)
Green wall	- Insulation - Influence on air quality	Staffordshire, UK	Chiquet et al. (2013)
Grasses planted in tram tracks	- Microclimate regulation - Influence on air quality	Stuttgart, Germany	Kazmierczak and Carter (2010)
Street/roadside trees	- Microclimate regulation - Influence on air quality - Encourage species diversity - Wildlife habitat	Toronto, Canada; Stuttgart, Germany; Vantaa, Helsinki, Finland	Kazmierczak and Carter (2010), Ranta et al. (2015)
Tree plantation	- Urban flood prevention - Extreme event protection	Coastal provinces, Vietnam	McCarthy (2012)
Community garden	- Urban flood prevention - Microclimate regulation	Berlin, Germany	Kazmierczak and Carter (2010)
Park, pocket park, open spaces	- Microclimate regulation - Influence on air quality	Stuttgart, Germany	Kazmierczak and Carter (2010)
Continuous linear parks as greenways	- Noise abatement - Recreation - Social activities - Preservation of native trees, shrubs - Reduced soil erosion - Water purification	Campinas, Novo Horizonte and São José do Rio Preto, Brazil	Frischenbruder and Pellegrino (2006)
Greenbelt (network of parks, courtyards, squares, tree-lined streets and green roofs)	- Noise abatement - Influence on air quality - Wildlife habitat/corridor - Recreation - Aesthetics	Dongtan & Shanghai, China	De Oliveira (2014)

2. Methods

2.1. Search and selection of studies

We searched electronic journal databases Science Direct and Springer Link to identify best practices, that is, green adaptation strategies already implemented worldwide for managing urban ecosystem services. Keywords for the search included ‘green and blue infrastructure’, ‘multifunctional infrastructure’, and ‘green adaptation’. From this, we chose 115 peer-reviewed publications ranging from 2005 to early 2016 for further selection of articles. We then examined literature containing empirical studies at city scales.

2.2. Household survey and expert interview

Our study area consisted of three wards (lowest administrative

Table 2
Green adaptations at city scale contributing to ecosystem services through urban blue management.

Green adaptations for managing blue spaces	Contribution to ecosystem services	Urban area (city, country)	References
Porous/permeable pavements	- Urban flood prevention - Storm water management	Toronto, Canada; Philadelphia, USA	Kazmierczak and Carter (2010), Maksimović et al. (2015)
Rainwater harvest (tank/barrel)	- Water supply - Emergency water supply for household use & firefighting - Urban flood prevention - Storm water quality & flow management - Aesthetics	Seoul, South Korea; Albury, New South Wales & Brisbane, Australia	Maksimović et al. (2015), Mitchell (2006)
Storm water retention pond	- Storm water management - Urban flood prevention - Aesthetics	Toronto, Canada; Augustenborg, Malmö, Sweden	Kazmierczak and Carter (2010)
Wetland preservation/artificial wetland creation	- Food availability - Storm water management - Urban flood prevention - Increase climate resilience - Biodiversity protection - Waste treatment - Water purification - Provision for industrial raw materials	Toronto, Canada; New Orleans, USA; Binzhou, China; Kolkata, India	Kazmierczak and Carter (2010), Wang et al. (2008), Bhattacharya et al. (2012)
Infiltration of runoff in large shallow ponds	- Groundwater recharge - Mitigate dropping groundwater levels	Los Angeles, USA	Porse, Glickfeld, Mertan, and Pincetl (2015)
Storm water bump-out & storm water planter boxes	- Microclimate regulation - Recreation - Aesthetics - Social activities	Philadelphia, USA	Kazmierczak and Carter (2010)
Watershed restoration	- Water supply - Wildfire risk management - Biodiversity protection	Santa Fe, USA	McCarthy (2012)
Bluebelt (connecting canal, lake, pond, minor waterways, wetlands)	- Increase resilience to natural hazards & extreme events - Shoreline protection - Coastal & riverine settlement protection	Dongtan & Shanghai, China	De Oliveira (2014), Betancourth (2011)
Water sensitive urban design (using grass swales, underlying gravel trench, artificial wetland, open space, ornamental lake)	- Storm water management - Aesthetics - Water purification (nutrients control)	Lynbrook Estate, Melbourne, Australia	Kazmierczak and Carter (2010)
Dual reticulation of non-potable treated wastewater for toilet flushing, garden watering, car washing	- Storm water flow & quality management - Water purification (nutrients control)	Sydney, Australia	Mitchell (2006)

boundary in urban area) under Mirpur-Pallabi Zone (Zone-2), Dhaka North City Corporation (DNCC) (Fig. 1). We selected wards 6, 7, and 8 based on field level observations, personal experiences, expert judgements, and literature review. These three wards covered 41% of Zone-2 (DNCC, 2017). The demographic (population, income level, literacy rate, gender ratio) conditions and land use patterns across the wards under DNCC were similar (BBS, 2013; DNCC, 2017). Furthermore, we considered the presence of a wide range of ecosystems in these wards, access to them and to households within wards for surveys.

To assess social acceptance of green adaptation strategies we conducted questionnaire-based surveys of 510 households from April to June 2016. We did a pilot survey beforehand for pre-testing the questionnaire and determining the sample size for the main survey. Dichotomous questions with answers of 'yes' or 'no' were assessed and the random sampling formula (Eq. (1)) from Cochran (1953) was applied to determine the sample size. We ensured that the randomly selected households covered as broad a geographic area as possible within the selected wards.

$$n = 1.96^2(P(1-P)/0.05^2)1.2 \quad (1)$$

Here, n = sample size, P = Proportion of beneficiaries selected, that is, percentage of preferred variable from 'yes' or 'no', 1.96 is the value of normal distribution at 5% level of significance implying that 95% of the area of a normal distribution is within 1.96 standard deviation of the mean, assuming 5% admissible error and 20% non-response rate (i.e., 20% more samples would be required).

There were 175 (34.3%), 174 (34.1%) and 161 (31.6%) respondents from ward 6, ward 7, and ward 8, respectively. About 63% of the respondents were male. The proportion of the females surveyed ranged from 31 to 44% across wards. Most respondents (42%) were aged between 35 and 45 years, held bachelor degrees (36%), and were married (91%). Average monthly household income was greater than 50 thousand BDT (Bangladeshi Taka; 78 BDT = 1 USD). Most of the respondents (66%) did not own their own houses and paid 5–10 thousand BDT rent per month. We asked randomly-selected respondents structured questions on selected green adaptation strategies (Table 3). In addition, we evaluated the respondents' willingness to pay (WTP) for implementing their preferred green adaptation strategy.

We undertook in-depth interviews of experts using a semi-structured format together with some open-ended questions to evaluate the economic feasibility of green adaptation strategies in Dhaka. Experts included researchers, academics, government officials, economists, architects, urban planners from local and international government and non-government organizations, and local senior citizens. They were from the International Centre for Climate Change and Development (ICCCAD); the International Union for Conservation of Nature (IUCN) Bangladesh; BanDuDeltAS; the World Bank; Climate Change and Health Initiative, the International Centre for Diarrhoeal Disease Research,

Bangladesh (ICDDR,B); Climate Finance Governance, Transparency International Bangladesh (TIB); Dhaka North City Corporation (DNCC); the Centre for Environmental and Geographic Information Service (CEGIS); Bangladesh Centre for Advanced Studies (BCAS); Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology (BUET); Department of Economics, East West University; Department of Development Studies, University of Dhaka; Centre for Climate Change and Environmental Research, BRAC University and Latitude-23, Dhaka.

3. Results

3.1. Green adaptations: A review

3.1.1. Urban green management

Table 1 presents implemented green adaptation strategies contributing to ecosystem services by urban green space management.

Table 1 presents evidence that anthropogenic construction of green spaces (i.e., green adaptation) contributes to ecosystem services management and generation. These include: mitigation of extreme heat arising from Urban Heat Island (UHI) effects; prevention of floods though rainwater retention; improvement of air quality by capturing fine dust; provision of UV-protection and carbon sequestration; conservation of biodiversity, and improvement of aesthetics.

3.1.2. Urban blue management

Blue spaces are important providers of ecosystem services in urban settings (Table 2). Blue spaces include: storm water management; urban flood prevention; microclimate regulation; water supply for irrigation, garden watering, toilet flushing, cleaning, washing, water purification by controlling nutrients; ground water recharge; biodiversity protection, and aesthetics.

3.1.3. Implementation of green adaptation strategies

Our review reveals that developing countries are prioritizing private gardens (Jim & Zhang, 2015) in response to rapid urbanization. León (Nicaragua) has private urban patios comprising 86% of its total green space whereas cities in developed countries- Stockholm (Sweden) and Dunedin (New Zealand) have 16% and 36% shares of private gardens in urban areas, respectively (Goddard, Dougill, & Benton, 2010). Campinas in Brazil delineated continuous linear park or greenways in a regional plan which has been implemented with local stakeholders including neighborhood association, firms, local high school, and public institutions for funding, maintenance, and monitoring (Frischenbruder & Pellegrino, 2006). Collective management of urban commons such as parks or community gardens can promote environmental stewardship and diversified learning streams (Lovell & Taylor, 2013). Restoration and protection of nature bring direct economic benefits in terms of increasing property values through improved aesthetics (McCarthy, 2012; Rahman, Ahmad, Mohammad, & Rosley, 2015). According to Francis and Lorimer (2011), green facades have long been used for aesthetic or horticultural purposes. There are many examples where NGOs and government promote conservation of biodiversity with green spaces (Goddard et al., 2010). Stuttgart (Germany) banned building in the hills around the city and prevented construction projects likely to obstruct night-time air ventilation (Kazmierczak & Carter, 2010). Berlin (Germany) promoted green courtyards and green roofs with public subsidies and Basel (Switzerland) successfully implemented regulations for green roofs (Kazmierczak & Carter, 2010).

Blue space management is more challenging. Building grey infrastructure (e.g. dikes, reservoirs, dams, sea walls) can influence natural systems and related ecosystem services (Betancourth, 2011). In Seoul, South Korea, rain water harvest tanks were installed in housing complexes and schools of which 36% were constructed only for storm water management (Maksimović, Kurian, & Ardakanian, 2015). Use of a constructed wetland for detoxification of industrial wastewater reduced water scarcity and pollution in Binzhou City, China (Wang, Yao, & Ju, 2008). Preservation of natural wetlands in east Kolkata, India helped in resource recovery based on combined aquaculture and agriculture practices which supported more than 20,000 families belonging to the low income bracket by creating food provisions- fish and vegetables (Bhattacharya, Ganguli, Bose, & Mukhopadhyay, 2012). In Brisbane, Australia rain water harvesting reduced potable water usage by more than 80% meeting 70–80% of household water demand (Mitchell, 2006). Green roofs, planted trees, open storm water systems and installed bat and bird boxes in Augustenborg, Malmö, Sweden increased biodiversity by 50% (Kazmierczak & Carter, 2010). Implementation of green adaptation strategies for managing urban blue spaces require extensive planning and government involvement. Melbourne Water (managed by the Victorian state government, Australia) created a green-field residential area (Maksimović et al., 2015). Philadelphia Water Department developed a green adaptation plan in collaboration with the private sector (Maksimović et al., 2015). Most cases cited above reveal participatory approaches as a key factor in successful implementation. Community-managed watershed restoration activities (including preparing local residents to manage it and local science-management partnership) in Santa Fe, USA proceeded with public grants (McCarthy, 2012). Similarly, in Augustenborg, Sweden, leadership, external collaboration, and empowerment of the local community resulted in retrofitting sustainable drainage systems in an urban regeneration area (Kazmierczak & Carter, 2010).

Often green adaptation strategies are implemented combining green and blue spaces. Examples include: water sensitive urban design in Lynbrook, Melbourne, Australia; sustainable urban drainage systems in Augustenborg, Malmö, Sweden; greenbelt and bluebelt in Dongtan and Shanghai, China. Managing urban green and blue spaces with green adaptation contributes to natural as well as socio-economic systems. Benefits include reduced energy demand, reduction in extreme heat events, availability of food, promotion of social activities, provision of psychological and health benefits. Furthermore, economic benefits accrue from increased land values, reduced costs of, for example, drainage construction and freely available food (Kazmierczak & Carter, 2010; Younos, 2011). Well managed ecosystems sometimes become objects of pride for local residents and raise awareness of the benefits of green adaptation (Frischenbruder & Pellegrino, 2006).

We find that green adaptation strategies are mostly implemented and studied in developed country contexts. They are in the planning phases in many countries (Kazmierczak & Carter, 2010) including Bangladesh. However, not all strategies are implementable everywhere. Geographic location and climatic conditions of the area, social acceptance, and economic feasibility of the strategies are thus important to take into consideration.

3.2. Citizens' preferences of green adaptations in Dhaka

3.2.1. Social acceptance of green adaptations

The respondents revealed their preferred green adaptation strategies/green adaptations that they considered to be implementable with individual (Fig. 2A) and collective (Fig. 2B) efforts and stated willingness to pay for the preferred strategies (Table 3).

Most of the respondents (85%) preferred rooftop garden/agriculture as the most implementable adaptation strategy by individuals, followed by green roof (22%), green façade/wall (14%), and rainwater harvest tank (14%). Ward 6 had the greatest number of respondents preferring rooftop garden/agriculture (95%), green roof (25%), and green façade/wall (17%). About 22% of the respondents in Ward 7 preferred rain water harvest tank: the highest of all wards surveyed. A total of 10% of the respondents preferred none of the nominated strategies. Those who did not believe green adaptations to be implementable were mostly from Ward 8 (22%).

Almost all the green adaptation strategies presented were preferred by the respondents for implementation with collective actions.

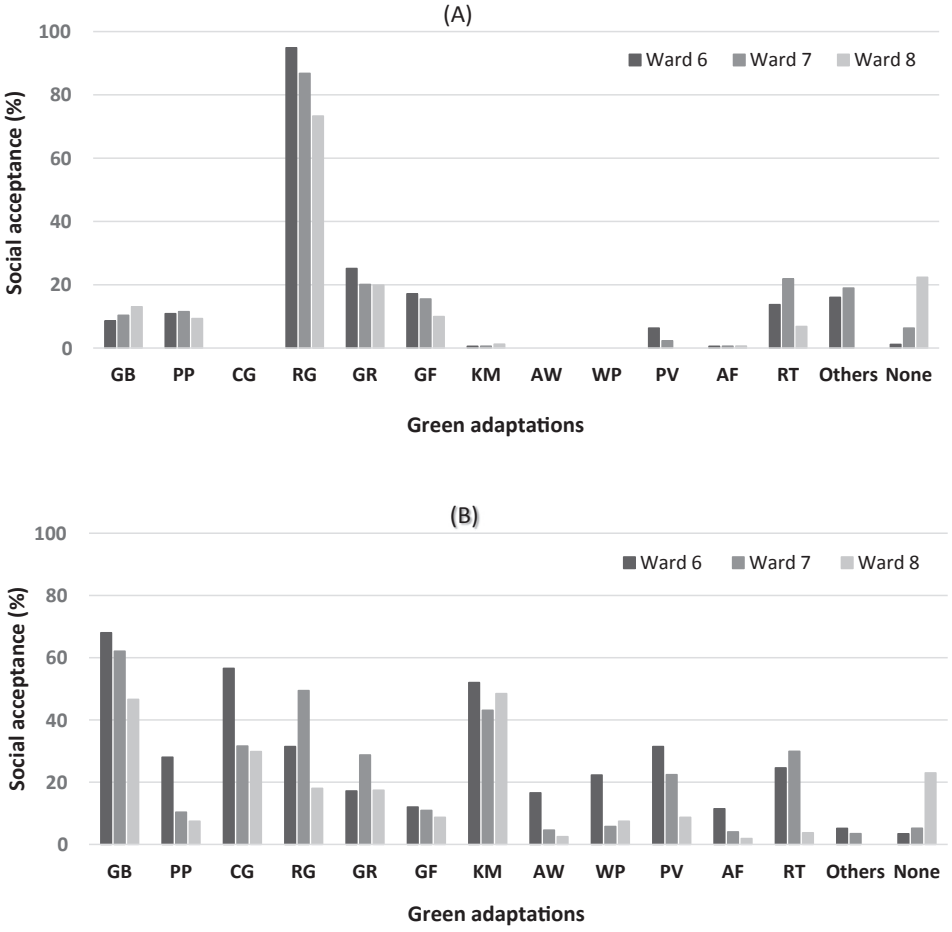

Fig. 2. Social acceptance (%) of green adaptations implementable with individual effort (A) and collective effort (B). Here, GB- Green belt, PP- Pocket park, CG- Community garden, RG- Rooftop garden/agriculture, GR- Green roof, GF- Green façade/wall, KM- Existing khal/lake management, AW- Artificial wetland, WP- Water retention pond, PV- Porous pavement, AF- Artificial fountain, and RT- Rainwater harvest tank.

Table 3
Summary statistics of the respondents' willingness to pay (WTP) for green adaptations for ecosystem services management.

Green Adaptations (GA)	Respondents WTP for GA (as % of total sample size, n = 510)	WTP (BDT per month)	
		Mean	Median
Green belt	29	109	69
Pocket park	6	80	64
Community garden	22	116	89
Rooftop garden/ agriculture	76	320	143
Green roof	20	366	105
Green façade/wall	4	104	75
Existing canal/lake management	29	237	72
Artificial wetland	0	55	55
Water retention pond	1	55	50
Porous pavements	4	62	20
Artificial fountains	0	0	0
Rain water harvest tank	9	107	94

Greenbelt development (tree plantation around neighborhoods) was preferred by about 60% of the respondents surveyed across all wards followed by existing khal (i.e., canal)/lake management (48%), and community garden development (40%). Artificial wetlands and fountains were the least preferred strategies. In most cases, Ward 6 had the highest percentages of the respondents' preferences. About 10% of the respondents considered that no green adaptation strategies were implementable even with collective efforts.

About 35% of the households surveyed had rooftop gardens of which almost 70% belonged to the owners of the houses. House front and house peripheral gardens were also identified (in about 5% of households surveyed). Many respondents had plants in balconies. Fig. 3 shows images of rooftop/balcony gardens in the study area. Fruit and flower gardens were identified in 32% and 29% of the cases, respectively. Mixed gardens (seasonal fruits, vegetables and flower/ornamental plants) were found in 36% of the houses. Common fruits grown in rooftop gardens included aam/mango (*Mangifera indica*), pepe/papaya (*Carica papaya*), lebu/lime (*Citrus aurantiifolia*), dalim/pomegranate (*Punica granatum*), peyara/guava (*Psidium guajava*), and jamrul/java apple (*Syzygium samarangense*). Vegetables included leafy vegetables, green chili, tomato and gourds of different kinds. The gardens were mostly maintained by the occupants who also consumed the fruit or vegetable products. Respondents considered that the gardens increased the aesthetic appeal of their houses.

In general, the respondents were selective in willingly paying for their preferred green adaptation strategies (Table 3). Of the 510 respondents, 76% were willing to pay for rooftop garden/agriculture with a mean payment of BDT 320 per month. Twenty-nine per cent of the respondents were willing to pay an average of BDT 109 and BDT 237 per month for greenbelt and existing khal/lake management, respectively. Relatively few respondents were willing to pay for artificial wetland, artificial fountain, water retention pond, green façade/wall, porous pavement, pocket park, or rain water harvest tank.

3.2.2. Economic feasibility of green adaptations

In-depth interviews showed that rooftop gardening was the most affordable green adaptation strategy for individuals in Dhaka (Fig. 4). Almost all nominated strategies were considered affordable with collective efforts: pocket park (100%), existing khal/lake management (100%), green roof (92%), rainwater harvest tank (92%), green façade/wall (92%), rooftop garden (88%), porous pavement (84%), and community garden (80%). Green roof, green façade/wall, and community

Fig. 3. Images of rooftop/balcony gardens in the study area. (A) A flower garden (front) and a fruit garden (back); (B) Fruits in a roof garden; (C) Reclining vegetables in a balcony.

garden were found to be not culturally appreciated in Dhaka. Notionally, green roof and façades were considered to detrimentally affect holdings. Community gardens and water retention pond necessitate common open spaces. There were provisions for open spaces/parks/play grounds/water retention areas in many residential areas but most were not functional. In a densely-populated city such as Dhaka with relatively high land prices, it is difficult to arrange common space without government intervention. Thus, greenbelt development, artificial wetlands, and artificial fountain construction entail higher government involvement as they require extensive planning, funding, and land.

The interviewees revealed concerns regarding implementation of green adaptation strategies even if affordable. They anticipated that citizens would willingly adopt such strategies if the benefits were visible and if the government facilitated their implementation. Costs of implementation would vary depending on location, size, land, labor, capital and technology requirements. Not all green adaptations were considered to be economically viable for citizens from every income groups.

3.2.3. *Social acceptance and economic feasibility: A comparison*

Table 4 compares citizens' preferences of green adaptation strategies for managing Dhaka's urban greens and blues and associated ecosystem services with respect to social acceptance and economic feasibility considering individual and collective efforts for implementation.

Rooftop garden/agriculture showed very high social acceptance for implementation by individuals (Table 4). This green adaptation was also considered to be very highly economically feasible/affordable for an individual. Most other nominated strategies had low social acceptance. Green roof, green façades/wall, and rainwater harvest tank were all considered to be affordable for individuals, but had low to moderate social acceptance.

Green adaptation strategies facilitated by collective efforts including: greenbelt/tree plantation around neighborhoods and existing khal/lake management were considered to have moderate social acceptance (Table 4). Existing khal/lake management was considered to be economically feasible for communal implementation but greenbelt development was assessed as having low to moderate economic feasibility for implementation in Dhaka without large-scale government involvement. Nonetheless, pocket park, green roof, rainwater harvest tank, green façades/wall, porous pavement, and community garden were found to be very highly feasible for implementation with collective efforts but with relatively low social acceptance.

4. Discussions and conclusions

We have shown that green adaptation strategies, prominent in many of the world's major cities, are beneficial to ecosystem services. For densely populated cities such as Dhaka, ecosystem services offer important environmental, social and economic benefits. These include adaptive responses to urban development such as, current pressures from demographic and land use changes as well as emerging climate change threats, particularly extreme heat, and extreme weather events. Ecosystem services offer benefits including reduced energy demand, increased land values, avoided cost of drainage maintenance, cool and

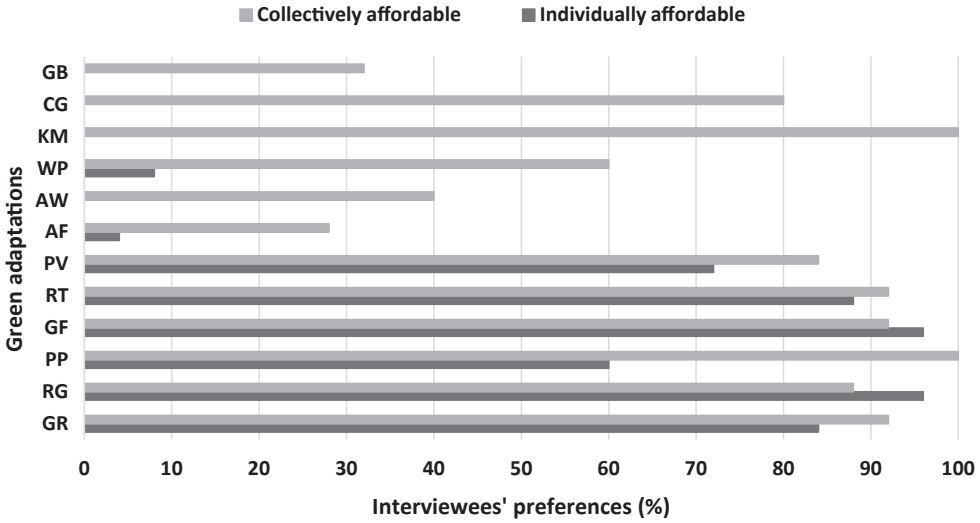

Fig. 4. Interviewees preferences (%) of green adaptations economically feasible to implement with individual and collective efforts. Here, GB- Green belt, CG- Community garden, KM- Existing khal/lake management, WP- Water retention pond, AW- Artificial wetland, AF- Artificial fountain, PV- Porous pavement, RT- Rainwater harvest tank, GF- Green façade/wall, PP- Pocket park, RG- Rooftop garden/agriculture, and GR- Green roof. Source: Authors' own field work.

Table 4
Social acceptance versus economic feasibility of green adaptations in Dhaka with individual and collective implementation efforts.

Green adaptations		Social acceptance	Economic feasibility
Individual effort	Green roof	+ +	+ + + + +
	Rooftop garden/ agriculture	+ + + + +	+ + + + +
	Pocket park	+	+ + +
	Green façade/wall	+	+ + + + +
	Rainwater harvest tank	+	+ + + + +
	Porous pavement	+	+ + + +
	Artificial fountain	+	+
	Artificial wetland	–	–
	Water retention pond	–	+
	Existing khal/lake management	+	–
	Community garden	–	–
	Green belt	+	–
Collective effort	Green roof	+	+ + + + +
	Rooftop garden/ agriculture	+ +	+ + + + +
	Pocket park	+	+ + + + +
	Green façade/wall	+	+ + + + +
	Rainwater harvest tank	+	+ + + + +
	Porous pavement	+ +	+ + + + +
	Artificial fountain	+	+ +
	Artificial wetland	+	+ +
	Water retention pond	+	+ + +
	Existing khal/lake management	+ + +	+ + + + +
	Community garden	+ +	+ + + + +
	Green belt	+ + +	+ +

Note: Very high preference + + + + +, High preference + + + +, Moderate preference + + +, Low to moderate preference + +, Low preference + and No preference –. Preference scores were categorized based on percentages shown in Figs. 2 and 4.

clean environment, higher social interaction, psychological and health benefits (Jim & Chen, 2008; Liu & Li, 2012; Watson, Ricketts, Galford, Polasky, & O'Niel-Dunne, 2016).

Our surveys of Dhaka households and interviews with experts revealed that rooftop garden/agriculture had very high social acceptance and economic feasibility for implementation as a green adaptation strategy. Vegetation in dense urban settings can mitigate the urban heat island effect: thermal accumulation exacerbated through hard surface heating and convection. Shading and evapotranspiration from urban trees and other vegetation create an "oasis effect" lowering ambient temperatures (Zhang, Xie, Gao, & Yang, 2014). Berry, Livesley, and Aye (2013) showed that trees in urban settings caused up to 9 °C reduction in wall surface temperature and up to 1 °C reduction in external air temperature. Giridharan, Lau, Ganesan, and Givoni (2008) demonstrated increasing tree cover (by 25–40%) in dense residential development areas could reduce urban heat island intensity by a further 0.5 °C. Rooftop gardens also provided direct economic benefits such as fruit and vegetable produce: an incentive for residents to further develop gardens (see also Islam., 2002). Rooftop gardening was common in Dhaka particularly among home owners (rather than lessees).

The respondents were generally selective when expressing their willingness to pay for green adaptation strategies. Few were willing to pay for artificial wetlands, artificial fountain, water retention pond, green façade/wall, porous pavement, pocket park, and rain water harvest tanks. Possibly, Dhaka residents were not culturally familiar to these adaptation strategies and might be unaware of their benefits. Many respondents supported collective action, particularly from the government, for the construction and maintenance of communal adaptation measures, e.g., parks, community gardens, greenbelt, and water features. Social and economic benefits of green adaptations are expected to outweigh environmental benefits as their contribution in generating non-marketed ecosystem services including microclimate regulation, air pollution control, flood prevention are not generally valued in monetary terms. For Dhaka, a densely-populated city with scarce available land, public commitment to green spaces is relatively costly. Behavioral changes through awareness raising campaigns are necessary. Enforcement of laws and strong commitment from the government's end will be beneficial but, so far, this has not been forthcoming.

Blue space adaptations were not as popular as green spaces in considering ecosystem services and their utility in Dhaka. Probably, this is because (as the respondents in this study reported) blue spaces (water features) are mostly polluted, malodourous, and harbor mosquitoes and other pests. Yet blue spaces offer many benefits through ecosystem services. Bonan (2000) studied microclimate variability at a neighborhood level in Colorado, USA during different seasons and found that irrigated areas were cooler than non-irrigated areas. Kim et al. (2008) found restoration of the Cheonggye stream (5.8 km long), an inner-city stream in Seoul, Korea contributed to a 0.4 °C average local surface temperature reduction (with a maximum 0.9 °C) during daytime.

For developing countries, citizens forgo green adaptations for urban development: the basic necessities of housing are considered more important than green adaptation strategies. Most successful green adaptation implementation followed participatory approaches such as public engagement and collaborative activities.

Our analysis is based on a relatively small spatial scale and sample size due to time and resource constraints. While differences in preferences were shown by the respondents from the three wards surveyed, these are to be analyzed as part of a separate paper. Economic feasibility analysis in a quantitative manner could provide better input to the respondents for decision making and provide an empirical framework to influence government policy for green adaptation strategies in response to climate change. Yet we have revealed affordable practical adaptation strategies for a city struggling to adapt to urban development and climate change.

The densely-populated city of Dhaka (like many other mega cities in Asia) presents challenges associated with the affordability and practicality of maintaining green adaptation strategies and related ecosystem services given widespread poverty and the relatively high price of land (for green and/or blue spaces). Even so, for a climate exposed city, green adaptation may be not only desirable but essential to avoid catastrophic impacts of extreme weather events exacerbated by the built environment. Our review and empirical analyses suggest that successful green adaptation will require public participation at all stages. Social acceptance and economic feasibility analyses for green adaptation strategy implementation might be useful in decision making. Green adaptations will potentially solve 'brown' issues (Williams, 1997) related to ecosystems (air pollution, waste discharge, drainage) and make cities more resilient to pressures from demographic change and from climate change. It will increase the attractiveness of landscapes with associated benefits. An environmentally sustainable city ensures citizens quality of life and social justice (Savage, 2006). We consider our analysis as a first step which could serve as a basis for in-depth analysis for sustainable urban environmental management in Dhaka. Such research would be valuable for other cities in Bangladesh and in other developing countries similarly exposed to climate change and urban population growth.

Acknowledgements

This paper has been prepared as part of the doctoral research project "Green Adaptation for Ecosystem Services Management in Dhaka: A Socio-economic Evaluation" (project number: CF15/4498 – 2015001949) and funded through Monash Sustainable Development Institute and Monash University, Australia. We are grateful to Professor Michael Ward for advice. We are thankful to the interviewees, the respondents and everyone who helped us with data collection in Dhaka and encouraged for this publication. We thank the anonymous

reviewers and the concerned editor who provided constructive comments on a previous version of this paper.

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